ECONOMIC RESULTS, GULF OF ALASKA SHELF PROVINCE

(James D. Craig)

INTRODUCTION

This section summarizes the results of economic modeling using the *PRESTO-5* (*P*robabilistic *R*esource *EST*imates-*O*ffshore, version 5) computer program. The economic assessment results are influenced, to a large degree, by the undiscovered, conventionally recoverable oil and gas resources assessed using the *GRASP (G*eologic *R*esource *AS*sessment *P*rogram) computer model. The conventionally recoverable results are discussed in separate .pdf files (*Summaries of Play Results, with Cumulative Probability and Ranked Pool Plots*).

Each province summary page includes three illustrations: (1) cumulative probability plots for risked, conventionally recoverable resource distributions (oil, gas, and BOE); (2) a table comparing risked, mean, conventionally recoverable resources with the risked, mean, economically recoverable resources at current commodity prices; and (3) a price-supply graph displaying economically recoverable resource curves.

The province summary page is followed by a table reporting play-specific, economically recoverable resource estimates for two representative price scenarios: a Base Price scenario ($18/bbl-oil, $2.11/MCF-gas) representing current market conditions; and a High Price scenario ($30/bbl-oil, $3.52/MCF-gas).

PROVINCE SUMMARY PAGE

Risked Cumulative Probability Distributions

The province summary page provides, at page top, cumulative probability distributions for risked, undiscovered endowments of conventionally recoverable oil, gas, and BOE, where resource quantities are plotted against “cumulative frequency greater than %.” A cumulative frequency represents the probability that the resource endowment is equal or greater than the volume associated with that frequency value along one of the curves. For example, a 95% probability represents a 19 in 20 chance that the resource will equal, or be higher than, the volume indicated. Cumulative frequency values typically decrease as resource quantities increase. An expanded description of cumulative probability plots is given in “*Summaries of Play Results, with Cumulative Probabilities and Ranked Pool Plots* ” provided as a separate .pdf file.

Table of Risked Play Resources

The province summary page provides, at page center, a table comparing the total conventionally recoverable endowment and the smaller quantity of economically recoverable resources that could be profitably extracted under current economic and engineering conditions. Current prices are represented as $18 per barrel of oil and $2.11 per MCF of gas, where gas price is linked to oil price by energy equivalency and discount-value factors (5.62 MCF per barrel; 0.66 value discount). Conventional resource volumes correspond to points on the cumulative probability distributions (at page top). Economic resource volumes correspond to points along the mean price-supply curve (at page bottom). Resources listed as negligible (negl) have volumes lower than the significant figures shown. Not Available (N/A) means that these resources are unlikely to be produced in the foreseeable future because of reservoir conditions or the lack of a viable transportation infrastructure.

The ratio of economic to conventional resources indicates the proportion of the total undiscovered endowment that is profitable to produce under current commodity prices with proven engineering technology. However, for production to occur, commercial discoveries must be made, and the analysis does not imply discovery rates. Given the size and geologic complexity of the offshore provinces, exploration will require extensive drilling, and considering the relatively low chance of commercial success and the high cost of exploration wells, many of these frontier provinces are not likely to be thoroughly tested in the foreseeable future. The ratio of economic to conventional resources should be regarded as an opportunity indicator, rather than as a direct scaling factor for readily available hydrocarbon reserves.

Price-Supply Curves

The province summary page includes, at page bottom, a graph showing price-supply curves representing Low, Mean , and High resource production scenarios. Price-supply curves illustrate how volumes of economically recoverable resources increase as a function of commodity price. Characteristically, increases in commodity price result in corresponding increases in economically recoverable resource volumes. The economic resource volumes represent oil and gas, as yet undiscovered, that could be recovered profitably given the modeled economic and engineering parameters. At very high prices, the mean curve approaches the mean total resource endowment estimated by *GRASP*. The price-supply curves do not imply that these resources will be discovered or produced within a specific time frame, only that the opportunity exists for commercial production at levels controlled by commodity prices.

The price-supply curves were generated by the *PRESTO-5* computer program, which simulates the exploration, development, production, and transportation of pooled hydrocarbons in geologic plays within a petroleum province. Economic viability depends on the interaction of many factors defining the size and location of the hydrocarbon pools, the reservoir engineering characteristics, and economic variables relating expenditures to income from future production streams. The economic simulation is quite complex, owing to the complexities in the state of nature, and requires a sophisticated analytical model.

The following is a brief overview of the *PRESTO-5* modeling process. Geologic parameters (for example, reservoir thickness, pool area, risk) used by the *GRASP* computer model to determine conventionally recoverable resources are transferred into the *PRESTO-5* model through an interface program. Economic viability is determined by performing a discounted cash flow analysis on the expenses and modeled production stream for each pool simulated in a given trial. A Monte Carlo (random sampling) process selects engineering parameters (for example, production rate profiles, well spacing, platform installation scheduling), and cost variables (for example, platforms, wells, pipelines) from ranged distributions. Each simulation trial models the expenses, scheduling, and production for pools "discovered" within a particular play. The sampling process is repeated for productive pools in all geologic plays, and the economic resources are aggregated to the province level. The development simulation process is repeated, typically for 1000 trials, at given set of prices (oil and gas prices are linked). After the specified number of trials are completed for the first set of oil and gas prices, a new set of prices is selected and another round of simulation trials is run. This process continues for approximately 30 iterations, yielding a range of economic resource volumes tied to commodity prices. The results for all runs are given as probability distributions, where selected probability levels can be displayed as continuous price-supply curves.

These analyses determine the resource volumes that are commercially viable under a specific set of current economic and engineering assumptions. No attempt was made to upgrade engineering technology or development strategies that might be implemented in response to higher commodity prices.

The price-supply curves provided in this report are based on the most likely development scenario tailored for each particular province. All provinces were modeled on a stand-alone basis, with engineering assumptions designed for the primary hydrocarbon substance (oil or gas) identified by the *GRASP* analysis. Generally, the secondary hydrocarbon is less economically viable and places an extra burden on the primary hydrocarbon substance. For provinces without existing oil and gas infrastructure, the modeling scenarios were designed assuming that the primary substance would drive initial development in a particular province. Oil-prone provinces were modeled as "oil-only" production, with gas reinjected for reservoir pressure maintenance to maximize oil recovery. Gas-prone provinces were modeled with both gas and oil production because natural gas-liquids (or condensates) are not reinjected. Often the volume of condensates in gas-prone provinces exceeds any volume of non-associated crude oil. All hydrocarbon liquids are commingled in production and transportation systems.

This economic analysis assumes 1995 as the base year. Higher <u>nominal</u> commodity prices in the future (price increases only at the rate of inflation) do not result in higher estimated volumes of economically recoverable resources, whereas higher <u>real</u> commodity prices (increases above the rate of inflation) do increase the economically recoverable resources. The economic model assumes that commodity price and infrastructure costs were inflated equally at an assumed 3% annual inflation rate (flat real price and cost paths). The price-supply curves can be used to project economic resource volumes relative to future price if appropriate discounting back to the 1995 base year is made to account for real price and real costs changes in the intervening years.

The price-supply graph usually contains three curves, corresponding to Low, Mean, and High resource production levels. The Low resource case represents a 95% probability (19 in 20 chance) that the resources are equal to, or exceed, the volumes derived from the price-supply curves. The High resource case represents the 5% exceedance level (1 in 20 chance). The Mean resource case represents the average. In high-cost and high-risk provinces, where there are no economically recoverable resources at the 95% probability level, no "Low" curve is displayed. An apparent anomaly is observed in some cases where the lower tail of the "Mean" price-supply curve indicates economic resources greater than the "High" (5% probability) curve. This situation occurs at low prices where the probability of economic success drops below 5%, and the Mean curve is obtained from the few productive trials occurring at probabilities below 5%.

A few additional observations concerning price-supply curves are noteworthy. Following established convention for price-supply curves, these graphs are rotated from the usual mathematical display of X-Y plots. Although shown along the vertical (Y) axis, price is the independent variable and resource is the dependent variable. In many of the gas-prone basins, price-supply curves will display an abrupt step below which no risked economically recoverable resources are modeled. This step corresponds to the minimum resource value required to overcome the cost of production and transportation infrastructure. Because of the distances to Asian markets, the assumed destination for Alaska gas production, natural gas must be converted to liquid form for transportation by ships. The infrastructure associated with conversion into liquefied natural gas (or LNG) does not lend itself to incremental additions for grassroots projects; therefore, an abrupt "cost-hurdle" created by large LNG and marine terminal installations must be overcome by significant resource volumes.

Finally, the reader must be aware that these price-supply curves are models of <u>risked</u> hydrocarbon resources. Both the <u>geologic risk</u> that the resources are pooled and recoverable as well as the <u>economic risk</u> that development is profitable under the assumed economic and technologic conditions are factored into the reported results. This means that although very low resource volumes are reported as "economically recoverable", these low volumes, in fact, do not correspond to actual quantities of oil or gas. At low prices, risk is dominated by economic factors associated with engineering cost and reservoir performance variables. At high prices, risk is dominated by geologic factors related to volumetric variables. **Risked price-supply curves are most appropriately used to define the comparative potential of petroleum provinces under changing price and probability conditions.** They do not predict the timing of resource discovery or rate of conversion of undiscovered resources to future production. As previously stated, future production of the modeled economically recoverable resources will require extensive exploration programs. In the Alaska offshore, future leasing and exploration activities are likely to be driven by "high-side potential", combining perceptions of greater rewards at higher risk, higher future commodity prices, and innovative technology to reduce costs.

TABLE FOR PLAY RESOURCE DISTRIBUTIONS

The risked mean contribution for each geologic play in the province is tabulated under two hypothetical price conditions. The Base Price ($18 per barrel-oil; $2.11 per MCF-gas) represents current economic conditions. The High Price ($30 per barrel-oil; $3.52 per MCF-gas) represents a situation where <u>real price</u> has increased significantly from current levels. Other economic parameters (for example, discount rate and corporate tax rate) were equal in both scenarios, as were engineering technology and cost assumptions. The play number, name, and *UAI* (*U*nique *A*ssessment *I*dentifier code) provide a link to the data presented in other sections of this report. Hydrocarbon substances are distinguished as oil (includes crude oil and gas-condensate liquids), gas (includes non-associated, associated, and dissolved gas), and BOE (gas volume is converted to barrel of oil equivalent and added to oil volume).

GULF OF ALASKA SHELF MODELING RESULTS

The Gulf of Alaska shelf province was modeled for the production of oil only. Gas resources are not reported in the present economic assessment. This modeling decision was based on two considerations. First, the resources were modeled as associated oil/gas pools (oil reservoirs overlain by gas caps). Second, there is a noticeable negative economic impact on the primary hydrocarbon (oil) if associated gas resources are co-produced. The extra burden is caused by the high cost of liquified natural gas (LNG) processing and transportation infrastructure. Accordingly, the economic assessment assumed that reservoirs in gas caps would not be completed and solution gas separated by topside equipment would be reinjected for reservoir pressure maintenance. Although the emphasis of development in the near future would be oil production, associated gas resources could become available at some future time when oil pools are depleted below a commercial limit.

At present, there is no production and transportation infrastructure for offshore development on the Gulf of Alaska shelf. The development scenario assumed that new infrastructure would be located in Yakutat Bay, including a pipeline landfall, tank farm, and marine export terminal. Produced oil would be delivered to U.S. West Coast ports by tankers from the Yakutat facility. It was assumed that Los Angeles would be the principle receiving port, with route distance from Yakutat of approximately 2200 miles. Because the plays in this province are scattered (generally not overlapping), high development costs were incurred for subsea pipelines to gather produced oil to the central terminal in Yakutat. These gathering lines ranged from 30 to 250 miles in length. Offshore loading was not considered to be feasible because of common, severe storms in the Gulf of Alaska.

Under the Base Price condition ($18 per barrel), the Gulf of Alaska shelf contains 0.05 BBO of risked mean economically recoverable oil, or 8% of the mean conventionally recoverable oil endowment (0.63 BBO). At the High Price condition ($30.00 per barrel), the Gulf of Alaska shelf could hold 0.12 BBO of economic oil, or 19% of the mean oil endowment. If we assume a $30 per barrel price (1995$) and a High resource case (1 in 20 chance), 0.30 BBO of risked economic oil is estimated to be recoverable from this province. This very optimistic model is comparable to the <u>mean</u> economic oil recoverable from the Cook Inlet at <u>current</u> prices (0.27 BBO at $18). The low (8%) ratio between economic and conventionally recoverable oil suggests that most of oil resources occur in small, sub-commercial pools. The lack of economic viability is explained by generally small pool size and high proportions of gas in reservoirs, which cannot support the cost of new infrastructure in the Gulf of Alaska province.

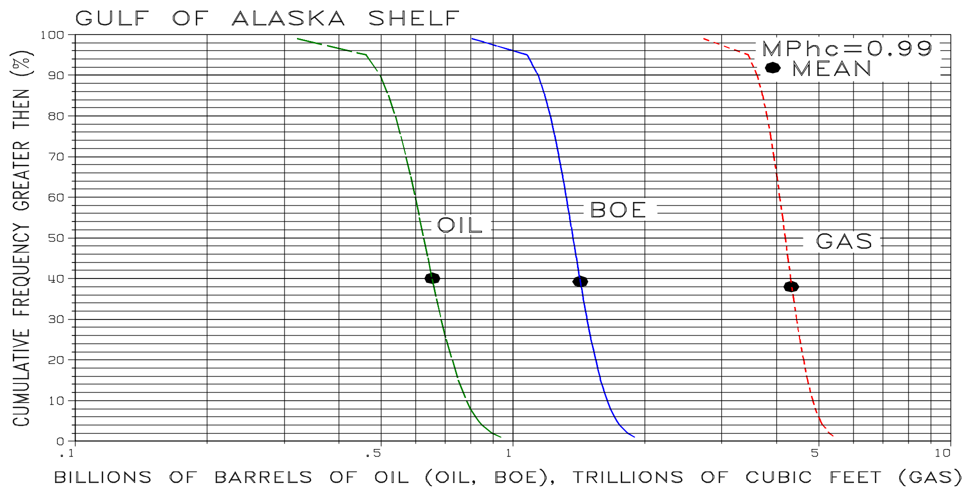
Economic oil resources are expected in 4 of the 5 recognized geologic plays in the Gulf of Alaska shelf province, the exception (Middleton Fold and Thrust Belt, Play 5) being a gas-prone play. However, 70% of the economic resources under the Base Price condition ($18) occurs in Kulthieth Sand play (Play 4). For the High Price condition ($30), 76% of the economic oil resources occur in the overlapping Basal Yakataga Formation (Play 3) and Kulthieth Sands (Play 4) plays.

Previous exploration efforts in the Gulf of Alaska shelf province have concentrated on easily identified structural prospects, and 12 exploration wells failed to discover commercial quantities of oil or gas. Future exploration interest is likely to be driven by expectations of high-side potential (which accepts higher rewards at higher risk), higher future commodity prices, and perhaps improved seismic techniques focused on stratigraphic prospects in plays 3 and 4.

Economic Results for Gulf of Alaska shelf assessment province. (A) Cumulative frequency distributions for **risked, undiscovered conventionally recoverable resources**; (B) Table comparing results for conventionally and economically recoverable oil and gas; (C) Price-supply curves for **risked, economic oil** at mean and high (F05) resource cases.

BOE, total oil and gas in energy-equivalent barrels; MPhc, marginal probability for occurrence of pooled hydrocarbons in basin; BBO, billions of barrels; TCFG, trillions of cubic feet.

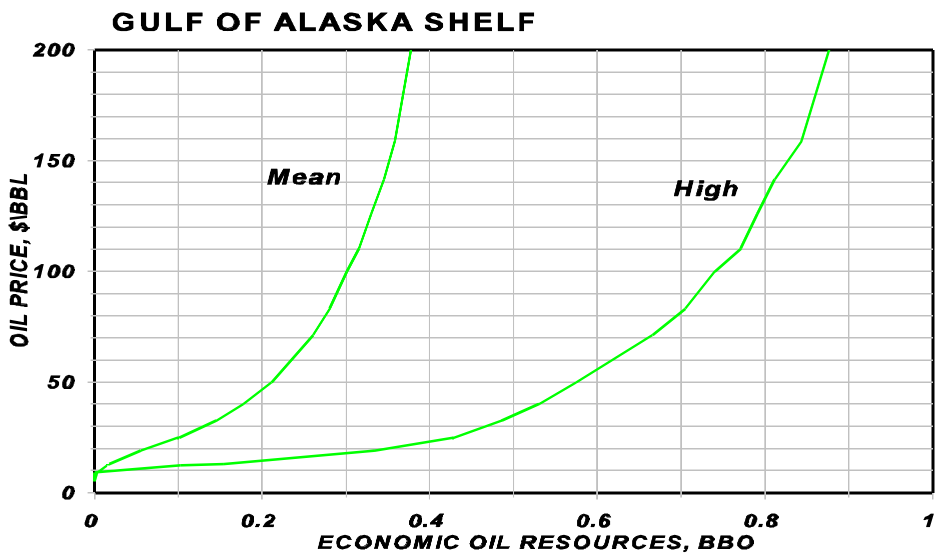
A.



B.

GULF OF ALASKA SHELF PROVINCE		
RESOURCE TYPE	**MEAN OIL (BBO)**	**MEAN GAS (TCFG)**
CONVENTIONALLY RECOVERABLE	**0.63**	**4.18**
ECONOMICALLY RECOVERABLE ($18)	**0.05**	**N/A**
RATIO ECONOMIC/CONVENTIONAL	**0.08**	**N/A**

C.



OIL AND GAS RESOURCES OF GULF OF ALASKA SHELF PLAYS

Risked, Undiscovered, Economically Recoverable Oil and Gas

PLAY NO.	PLAY NAME (UAI* CODE)	BASE PRICE			HIGH PRICE		
		OIL	GAS	BOE	OIL	GAS	BOE
1.	Middleton Fold and Thrust Belt (UAGA0101)	0.000	n/a	0.000	0.000	n/a	0.000
2.	Yakataga Fold and Thrust Belt (UAGA0201)	0.004	n/a	0.004	0.017	n/a	0.017
3.	Yakutat Shelf-Basal Yakataga Fm. (UAGA0401)	0.007	n/a	0.007	0.021	n/a	0.021
4.	Yakutat Shelf-Kulthieth Sands (UAGA0501)	0.032	n/a	0.032	0.069	n/a	0.069
5.	Southeast Alaska Shelf Subbasin	n/e	n/e	n/e	n/e	n/e	n/e
6.	Subducting Terrane (UAGA0701)	0.003	n/a	0.003	0.012	n/a	0.012
	TOTAL	***0.046***	***n/a***	***0.046***	***0.119***	***n/a***	***0.119***

* *Unique Assessment Identifier, code unique to play.*

OIL is in billions of barrels (BBO). **GAS** is in trillion cubic feet (TCF).
BOE is barrel of oil equivalent barrels, where 5,260 cubic feet of gas = 1 equivalent barrel-oil

For direct comparisons among provinces, two prices are selected from a continuum of possible price/resource relationships illustrated on price-supply curves. **BASE PRICE** is defined as $18.00 per barrel for oil and $2.11 per thousand cubic feet for gas. **HIGH PRICE** is defined as $30.00 per barrel for oil and $3.52 per thousand cubic feet for gas. Both economic scenarios assume a 1995 base year, flat real prices and development costs, 3% inflation, 12% discount rate, 35% Federal corporate tax, and 0.66 gas price discount.

Shaded columns indicate the most likely substances to be developed in this province. Economic viability is indicated on price-supply curves which aggregate the play resources in each province.

N/A refers to “not available”. Associated gas will be reinjected for pressure maintenance to maximize oil recovery. Coproduction of gas resources severely affects the value of oil resources because of the high costs for LNG infrastructure.

N/E refers to “not evaluated”. Play has very high geologic risk.